

FREE OVERFALL (STRAIGHT DROP) SPILLWAYS – DESIGN GUIDELINES

A “Free Overfall” (or “Straight Drop”) Spillway is one wherein the flow freely drops from the crest of a weir wall that has a vertical or nearly vertical downstream face. The weir crest may be sharp-crested or broad-crested. In some designs, the crest may be extended in the form of an overhanging lip to direct flows away from the downstream face of the wall. The underside of the nappe of the falling jet of water is ventilated to prevent pulsations in the jet. The wall in which the weir crest is located is typically a reinforced concrete retaining wall. This type of spillway shall be limited to situations in which the differential head between the upstream (pond) water level and the tail water level (in the downstream channel) is less than 20 feet.

A properly designed stilling basin shall be provided as a part of the spillway structure to dissipate the energy of the falling water downstream of the weir wall. Three acceptable stilling basin types are: (1) Plunge Pool Basin, (2) Impact Blocks Basin, and (3) Hydraulic jump Basin. The Impact Blocks Basin typically is a more compact (shorter length) basin compared to the Hydraulic Jump Basin and its performance is not sensitive to the required tail water depth as in the case of a Hydraulic Jump Basin. Design methodologies given in the publications such as “Design of Small Dams” by the US Bureau of reclamation and Design Manuals of the US Department of Agriculture’s Natural Resources Conservation Service (NRCS) or the US Army Corps of Engineers are acceptable. If other designs or design methods are used, calculations in support of such designs shall be submitted for City’s review.

Plunge Pool Basin: A Plunge Pool Basin consists of an open basin, lined with concrete or riprap (placed on a geotextile for soil separation), of adequate length and of a depth (relative to the tail water level) of the plunge pool that is equal to the maximum scour depth of a free-falling jet. The length of the basin should be based on the trajectory of the falling water jet for the maximum design discharge. An empirical equation (based on experimental data) for the maximum scour depth is given in “Design of Small Dams” as follows:

$$D_s = 1.32 * (H_t^{0.225}) * (q^{0.54})$$

D_s = Maximum depth of scour below tail water level, in feet

H_t = Head differential between the head water and tail water levels, in feet

q = Discharge per foot width of the effective weir length, in cfs

The floor of the plunge pool basin would be provided at an elevation equal to or lower than the tail water elevation minus the maximum scour depth D_s . The tail water level should be determined based on the downstream channel flow characteristics (cross-section, slope, Manning’s roughness coefficient, or other downstream hydraulic controls if they exist).

Impact Blocks Basin and Hydraulic Jump Basin: Detailed procedures for determining the dimensions of the Impact Blocks Basin and Hydraulic jump Basin, including an example of design, are given in the chapter “Spillways” in the book “Design of Small Dams.” A summary of the procedures for Impact Block Basins (which is more compact/economical and less sensitive to variations in tailwater level) is provided here, for ready reference. For the design procedure of

Hydraulic Jump Basin (which is more complex), refer to the procedure and example given in the chapter on Spillways in the book “Design of Small Dams.”

The dimensions of the basins are given by the curves in the charts reproduced from the “Design of Small Dams” in the attached Figure, as functions of two independent variables: the “Drop Distance” (Y) and the “Unit Discharge” (q). The dimensions of the basins are given in the charts on the ordinate (in terms of Y) for a given value of the dimensionless “Drop Number” ($= q^2/gY^3$) on the abscissa. Since q^2/g is equal to $(d_c)^3$ (where d_c = critical depth of flow over the spillway), the Drop Number is also equal to $(d_c/Y)^3$.

The linear dimensions of the elements of an Impact Block Basin are as follows:

L_p is read off the attached chart (upper one)

Minimum length of basin = $L_b = L_p + 2.55 d_c$

Minimum length to upstream face of baffle block = $L_p + 0.8 d_c$

Minimum tailwater depth = $d_{tw} = 2.15 d_c$

Optimum height of baffle blocks = $0.8 d_c$

Width and spacing of baffle blocks = $0.4 d_c (+/-)$

Optimum height of end sill = $0.4 d_c$

Subsurface Seepage Considerations: In addition to determining the dimensions of the stilling basin from surface hydraulic considerations discussed above, the basin dimensions and thicknesses of the floor and walls of the basin structure should also be designed based on considerations of the uplift and lateral pressures associated with the subsurface seepage flow beneath and adjacent to the spillway and stilling basin structure, as it affects the global stability and structural strength of the elements of the structure. The length of the spillway and stilling basin structure shall also be checked for insuring against high “exit gradient” of seepage flow immediately downstream of the structure to prevent “piping” problem of soil particles from the foundation or backfill against the walls being carried away with seepage flow.

SPILLWAYS

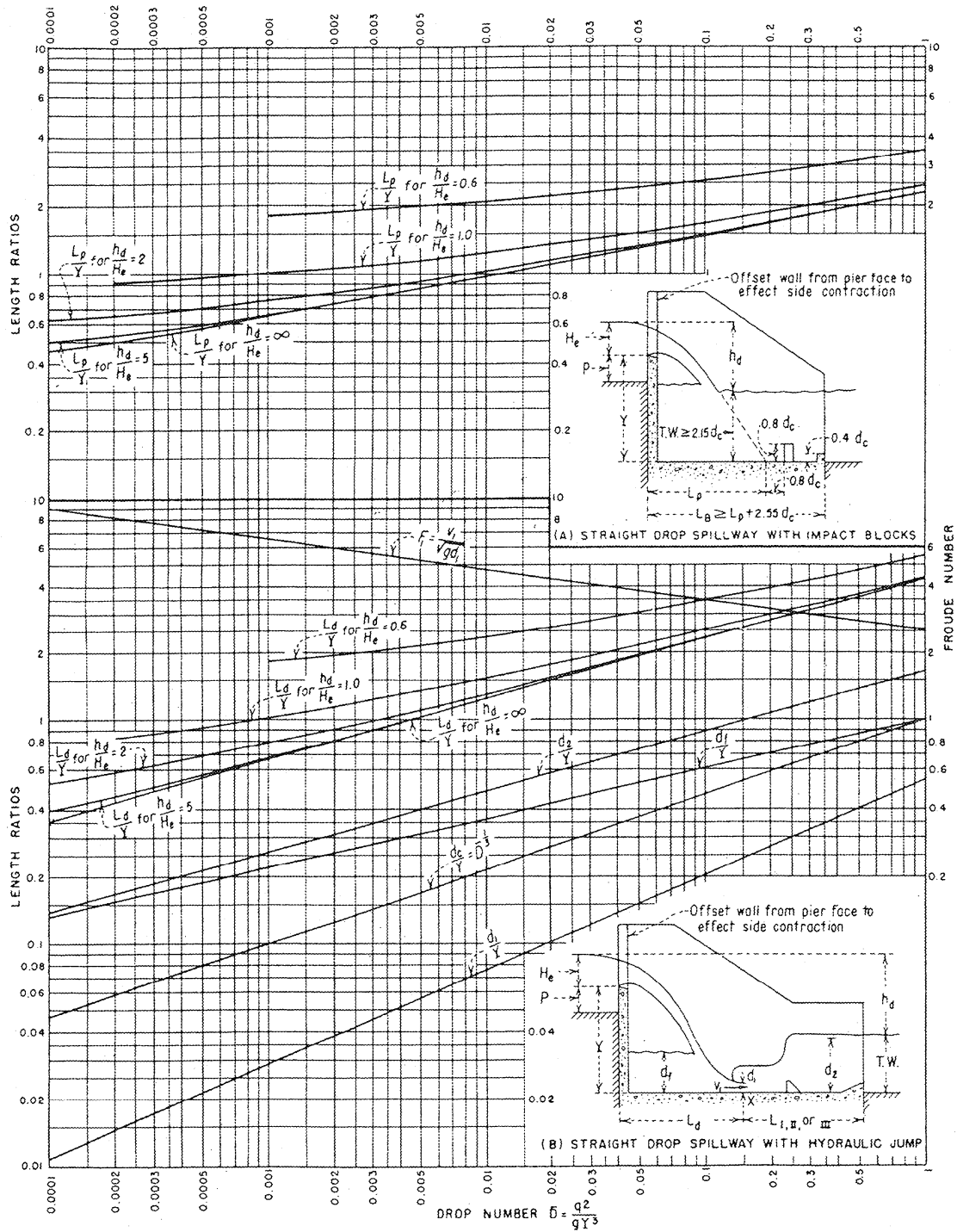


Figure 9-53.—Hydraulic characteristics of straight drop spillways with hydraulic jump or with impact blocks.
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